ORIGINAL ARTICLE

Asthma and air pollutants: a time series study

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Summary

Objective: To estimate the risk of hospitalization for asthma in children after exposure to air pollutants in a medium-sized city in Southeast Brazil. **Methods:** An ecological time series study was carried out with hospitalization data for asthma in children under 10 years of age living in São José dos Campos, SP, Brazil, and concentrations of particulate matter with aerodynamic diameter < 10 microns, sulfur dioxide, and ozone; data were also obtained on relative humidity and temperatures. Pearson's coefficient correlation was used for the study variables. To estimate the association between hospitalizations due to asthma and air pollutants, Poisson regression generalized additive models were built, according to lags of up to seven days. **Results:** There was a strong correlation between hospitalizations and the pollutants particulate matter and sulfur dioxide. Exposure to particulate matter and sulfur dioxide were associated with significant relative risks of 1.01 to 1.04 of hospitalization due to asthma on the same day and within three days after exposure. Increases in the concentrations of these pollutants increase the risk of hospitalization between 8% and 19%. **Conclusion:** There is evidence of the effect of air pollutants on asthma hospitalization in a medium-sized city in Southeast Brazil.

Keywords: Asthma; air pollutants; particulate material; sulfur dioxide; children's health; time series study.

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Introduction

Air pollution is defined as the presence of foreign substances in the air that affect the health and well-being of living beings[1]. This problem is likely to have adverse effects on health, even when pollutant levels are within the standards required by legislation.

The groups that are most susceptible to its adverse effects are children and the elderly[2,3]. For children, the fact is due to greater exposure to pollutants, increased minute ventilation, and higher levels of physical activity[4]. Among the effects of chronic exposure to air pollution in children and adolescents, one can highlight stunted development and decreased lung function, as well as the increased number of episodes of respiratory illness and hospitalizations[5,6].

The air pollutants associated with outcomes such as chronic diseases in children and increases in the risk of death are mainly particulate matter (PM_{10}), sulfur dioxide (SO_2), and ozone (O_3)[7]. In spite of evidence showing the association between exposure to air pollutants and damage to health, the mechanisms by which they cause these diseases are yet to be elucidated, but it is believed that the histological lesions caused by pollutants in the lung parenchyma may increase the harmful effects of viruses and/or allergens[8].

Exposure to PM_{10} is associated with increased morbidity through different mechanisms of action, including local inflammation, injury by oxidative stress, and endothelial dysfunction[9]. SO_2 is a respiratory irritant that has the capacity to deposit in the distal regions of the upper airways and lung parenchyma. Exposure to O_3, in turn, is associated with a decrease in lung function, increased reactivity and inflammation of airways, and altered macrophage function[10].

It is believed that the adverse effects caused by exposure to environmental pollutants have a performance lag, i.e., an individual exposed to a pollutant on a given day may present with an acute asthma attack a few days later[2].

Asthma, a chronic disease of genetic nature and environmental component, very common among children, is the main cause for the prolonged impairment of their health in developed countries, and shows a high prevalence in developing countries[11,12]. The disease is characterized by resulting from bronchial inflammation, with an exaggerated response of the lower airways and limited airflow in these airways[13]. It is estimated that about 10% of the world's population and 20% of the population of Latin America have the disease[14]; approximately 24% of Brazilian schoolchildren[15], with predominance of the male gender[16]. In addition to being a disease that poses a public health problem, asthma has a high socioeconomic impact[17]. The financial cost due to hospitalization for asthma in children and adolescents is around R$ 6 million for the federal and state government[18].

The present study aims to estimate the association between exposure to the air pollutants PM_{10}, SO_2, and O_3 and hospital admissions for asthma in children in São Jose dos Campos, state of São Paulo, Brazil.

Methods

The study was carried out in São José dos Campos, a mid-size city in the countryside of the state of São Paulo, Brazil. It is located at coordinates 23^0 10' S and 45^0 52' W, 600 m above sea level; its climate is altitude tropical humid. It has an important industrial sector and is transected by the most important and busiest highway in Brazil. It had an estimated population of just over 600,000 inhabitants in 2009. It is located between São Paulo and Rio de Janeiro, the two largest Brazilian cities, and is transected by Via Dutra, a highway with intense traffic[19].

This is an ecological time series study, which assessed hospitalizations for asthma (ICD10: J45) in individuals aged zero to ten years living in the city of São José dos Campos, from January 1, 2004 to December 31, 2005. Data were obtained from the Department of Information and Informatics of the National Health System[20]. Data on levels of the environmental pollutants PM_{10} and SO_2 were also selected, in their daily means, and O_3, in its daily eight-hour maximum levels, obtained from the Environmental Sanitation Technology Company, which has a measuring station in São José dos Campos[21]. PM_{10} was measured using a beta monitor, SO_2 was measured through the coulometry technique, and O_3, by chemiluminescence; all were quantified in $\mu g/m^3$. The temperature and humidity data were obtained from the Science, Space Technology and Applications Foundation[22].

Since there can be a gap behavior for the effects of pollutants, i.e., hospitalization occurs not only on the same day (lag 0), but also on subsequent days (lag 1, lag 2...), a lag template was constructed of zero to seven days for each of the pollutants in the study.

To estimate the risk of asthma hospitalization due to exposure to pollutants, Poisson regression generalized additive model was used. For this reason, the air pollutants were always analyzed together in a multipollutant model, adjusted for humidity, minimum temperature, and controlled by day of week and seasonality. The computer program used for this analysis was Statistica.

Results

During the study period, there were 841 hospital admissions for bronchial asthma in individuals aged 0-19 years living in São Jose dos Campos. The daily mean was 1.15 hospitalizations (SD = 1.26), ranging from zero to seven.

A total of 49 data on temperature and humidity were missing (6.7% of days), 26 related to O_3 (3.6%), 20 to SO_2 values (2.7%), and 31 to PM_{10} (4.2%). There were no

missing data regarding hospitalizations for asthma. These missing data did not affect the outcome of the study.

Mean values with their standard deviations, minimum, and maximum values and interquartile differences are shown in Table 1. Figure 1 shows that the PM_{10} and SO_2 have a seasonal characteristic.

Table 2 presents the correlation matrix between variables of the study. Hospital admissions for asthma showed a positive correlation with PM_{10} and SO_2, and a negative correlation with O_3. Among the pollutants, positive correlations were observed. The meteorological variables showed negative correlations with pollutants, except for ozone, which was positively correlated with temperature; as for hospitalization, there was a positive correlation with humidity and a negative correlation with temperature.

The months with the highest numbers of admissions were April, May, and June in both years of study, respectively, 54, 106, and 51 admissions in 2004 and 53, 52, and 54 in 2005.

Based on Poisson regression, with the three pollutants analyzed together, adjusted for minimum temperature and humidity and controlled per day of week and seasonality, regression coefficients were obtained and the respective standard-errors for each pollutant in each lag structure (Table 3). The relative risks and their 95% confidence intervals are shown in Figure 2.

Noteworthy is the combination that occurs on the same, second, and third days of exposure to PM_{10} and on the first, third, and sixth days after exposure to SO_2. The increase of 17 μg/m³ PM_{10} results in an increase in the relative risk of 16% and 19%; an increase in the concentration of SO_2 of 3 μg/m³ leads to an increase in the relative risk between 8% and 14%.

Discussion

There have been few studies on the effects of pollution as a cause of hospitalization due to asthma, and this is the first to be conducted in a mid-sized city such as São José dos Campos.

PM_{10} was the pollutant most often associated with hospitalizations for asthma, with statistical significance both on the same day of exposure and on the second and third days of exposure. In a study by Gouveia et al.[23], conducted in São Paulo, Brazil, it was observed that an increase of 10 μg/m³ in the levels of inhalable PM_{10} is associated with an increase of 4.6% in hospitalizations for asthma in children.

The levels of annual mean concentration of PM_{10} observed in this study exceeded the levels considered acceptable by the World Health Organization (WHO), and annual exposure levels above 70 μg/m³ are associated with

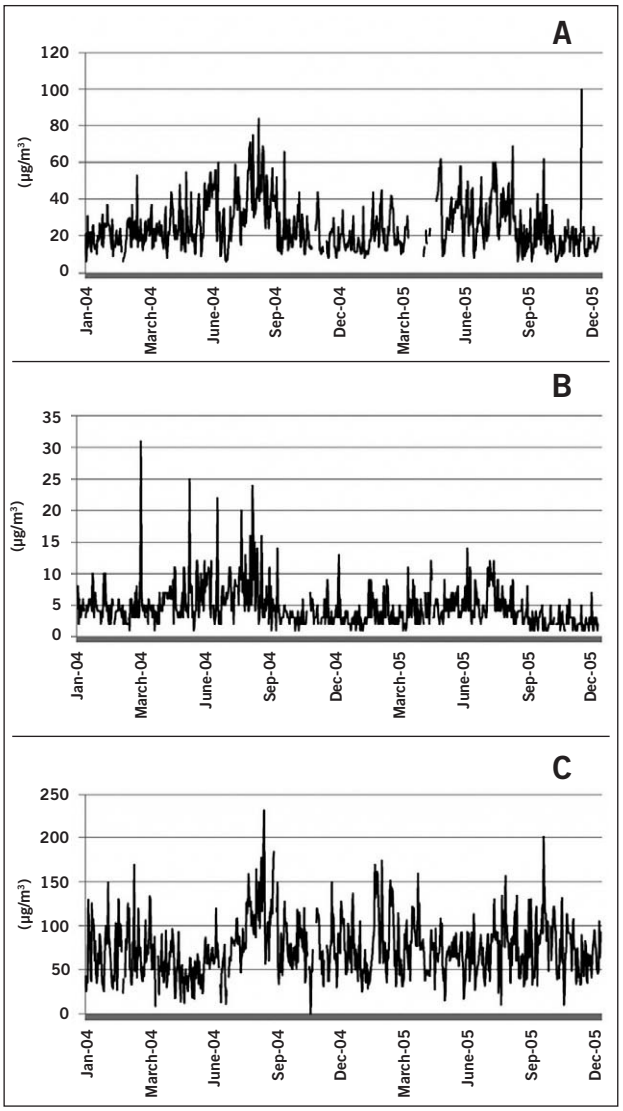

Figure 1 – Pollutants values (μg/m³), during the study period in São José dos Campos, SP, Brazil. (**A**) Particulate matter, (**B**) sulfur dioxide, (**C**) ozone.

Table 1 – Descriptive analysis of atmospheric variables – São José dos Campos, SP, Brazil, 2004-2005

Variables	Mean	SD	Minimum	Maximum	IQD
PM_{10} (μg/m³)	25.2	13.4	6.0	100.0	17.0
SO_2 (μg/m³)	4.6	3.2	1.0	31.0	3.0
O_3 (μg/m³)	74.3	32.4	9.0	232.0	41
Minimum temperature (°C)	15.4	2.7	7.4	20.5	4.0
Humidity (%)	79.6	6.8	54.0	99.3	19.3

SD, standard deviation; IQD, interquartile difference.

Table 2 – Pearson's correlation matrix between the meteorological variables – São José dos Campos, SP, Brazil, 2004-2005

Variables	Hospitalizations	PM_{10}	SO_2	Ozone	Temperature	Humidity
Hospitalizations	1.000	0.128**	0.157**	-0.025	-0.107**	0.090*
PM_{10}		1.000	0.494**	0.397**	-0.265**	-0.375**
SO_2			1.000	0.288*	-0.401**	-0.179**
Ozone				1.000	0.018	-0.510**
Temperature					1.000	0.266**
Humidity						1.000

**p < 0.01; *p < 0.05.

Table 3 – Coefficients of regression and respective standard-errors for air pollutants in all days of the analyzed lag structure – São José dos Campos, SP, Brazil, 2004-2005

	PM_{10}		SO_2		O_3	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Lag0	0.00922#	0.00349	0.02682#	0.01287	-0.00164	0.00148
Lag1	0.00573	0.00352	0.03354#	0.01336	-0.00028	0.00153
Lag2	0.01023#	0.00365	0.004488	0.01438	-0.00431	0.00153
Lag3	0.00864#	0.00352	0.03652#	0.01247	-0.00098	0.00149
Lag4	0.00198	0.00367	0.02963#	0.01512	-0.00181	0.00146
Lag5	0.00613	0.00371	0.02534	0.01416	-0.00101	0.00152
Lag6	0.00493	0.00394	0.03125#	0.01504	-0.00086	0.00149
Lag7	0.00564	0.00361	0.00678	0.01461	-0.00012	0.00146

SE, standard-error; #p < 0.05.

significant deleterious effects on health, leading to up 15% increase in mortality[24].

The study by Gouveia et al.[23] found a mean PM_{10} during the study period of 54.49 μg/m³, a much higher level than the one found in the present study, 24 μg/m³. The same occurred with the study conducted in Curitiba[2], which showed a mean of 90.39 μg/m³ for PM_{10}. A possible explanation for such differences would be the highest concentration of uncontrolled combustion in the cities of São Paulo and Curitiba, compared to São José dos Campos, as this is one reason for PM_{10} emission.

SO_2 was the pollutant most often associated with hospitalizations for asthma, presenting as a risk factor on the same day of exposure and after the first, third, and sixth days. A study that used Poisson regression analysis and was conducted in São Paulo, found a statistically significant positive association between asthma and this pollutant[23]. Likewise, SO_2 was also a risk factor, both when analyzed alone and when considered together with other pollutants on an average of four days, in the city of São Paulo[25]. The mean concentrations found in this study are within the range considered acceptable by the WHO, which accepts a maximum level of exposure of 20 μg/m³ for 24 hours[24].

In a study conducted in São Paulo, a mean SO_2 of 17.71 μg/m³ was observed, which differs from the value found in this study[23]. The same difference occurred when it was compared with a study carried out in the city of Rio de Janeiro, which showed a mean value of 18.59 μg/m³ for SO_2[26]. These facts can be explained by higher emissions of that pollutant in São Paulo and Rio de Janeiro, due to a larger vehicular fleet, one of the main sources of that air pollutant.

As for O_3, it was observed that this pollutant was not a statistically significant risk factor in any of the analyzed lag structures. The study by Bakonyi et al.[2] showed a statistically significant effect for O_3 only with a moving average of three days. This statistical difference may be due to the fact that their study variable were subjects aged 0-14 years of age treated for all respiratory causes, not just asthma, and also to the fact that they used moving averages and not lag structures, as in the present study.

The maximum daily concentration of this pollutant was 232 μg/m³, with a mean of 74.27 μg/m³ during 2004 and 2005. The manual of the WHO accepts a maximum level of exposure of 100 μg/m³ for 8 hours, for 1 day[24]. Levels above 240 μg/m³ are associated with significant effects on health, such as decreased lung function, airway inflammation, and hyperreactivity.

A mean of 71.79 μg/m³ of ozone was observed between 1996 and 2000 in São Paulo, which is very close

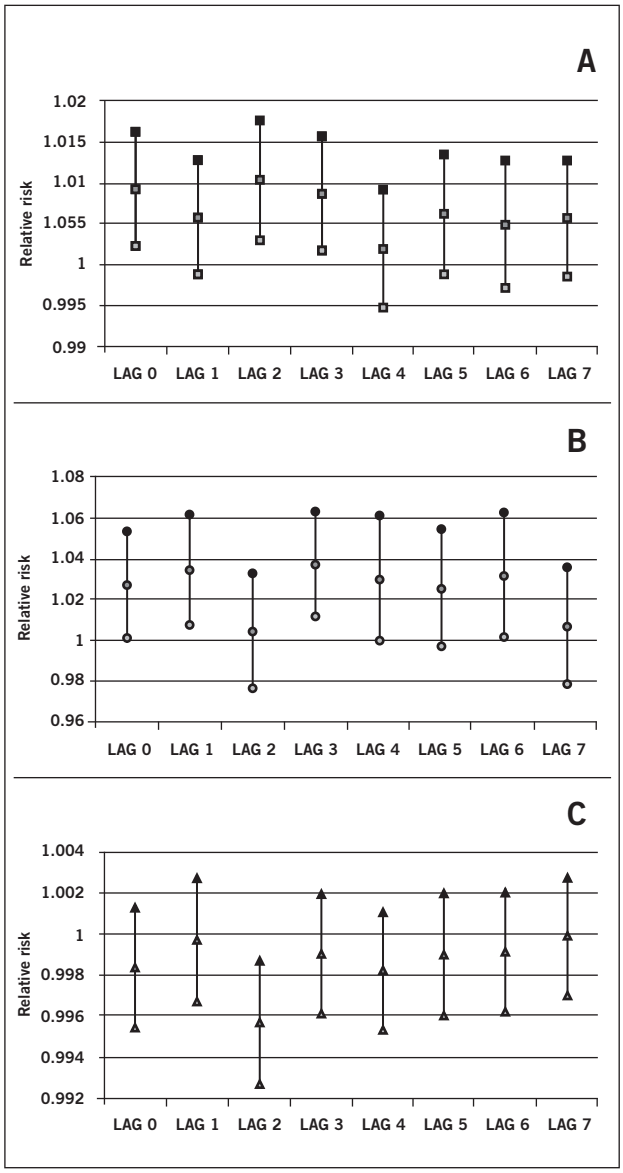

Figure 2 – Relative risks and 95% confidence interval of each pollutant in each lag structure in São José dos Campos, SP, Brazil, 2004-2005. (**A**) Particulate matter, (**B**) sulfur dioxide, (**C**) ozone.

to the value found in this study[23]. In other studies, in the cities of Curitiba and Rio de Janeiro, mean O_3 values of 63.71 μg/m3 and 81.08 μg/m^3, were observed, respectively, and these are also relatively close to the levels in this study[2,26].

In spite of the small magnitude of the RR found, the impact of air pollution on public health must be substantial, taking into account the large number of exposed individuals. The results shown here represent a quantitative approximation of the impact of air pollution on the population's health. It is important to emphasize that the outcome studied here, hospitalization, is just one of many effects caused by air pollution. Effects such as the occurrence of symptoms, medication use, school absenteeism, and reduced physical activity, among others, are not evaluated in this study. These, although considered to be minor effects to the individual's health, are of great importance to public health, given the high frequency at which they occur and due to their negative impact on quality of life and negative economic consequences, such as school and work absenteeism.

This study uses secondary data to calculate the coefficients and relative risks for hospitalizations resulting from increased levels of air pollution. These data come from very reliable and established sources[27,28] and are widely used in technical and scientific studies. The fact that the records refer to hospitalizations in public hospitals, which belong to the Public Health System (SUS), is noteworthy. Thus, the results shown here reflect the effects of air pollution in the population that uses this type of healthcare service, which accounts for the majority of the population.

On the other hand, information from the hospital information system of SUS used in this study are produced with financial goals and not strictly for epidemiological studies, and may thus have some degree of inaccuracy. They may have underestimated the frequency of certain diseases, considering the technological profile of the service network, as well as diagnostic coding errors. Another problem in this database is the possibility of counting the same patient twice, as the system does not identify hospitalizations. However, in ecological time series studies of daily basis, factors whose distribution does not vary daily do not act as potential confounders[27].

The quality of information on hospital admissions and other potential problems with this database does not vary from day to day and is not correlated with levels of air pollution. Therefore, its implications regarding the estimation of the observed effects are minimal. As for the concentrations of pollutants, O_3 exceeded the acceptable value of 160 mg/m^3 in 16 occasions, those of PM_{10} exceeded the value of 50 mg/m^3 in 21 days, and SO_2 did not exceed the values recommended by the National Council for the Environment (Conselho Nacional do Meio Ambiente – Conama)[29].

This study demonstrates that even populations of mid-sized cities may be affected by environmental pollution, resulting in an increasing incidence of hospitalizations for asthma and decreased quality of life of citizens.

Conclusion

The pollutants PM_{10} and SO_2 were identified as associated with hospitalization caused by asthma in a mid-sized city, and this information may be useful in the implementation of public health policies in the municipality.

References

1. Elson DM. Atmospheric pollution: a global problem. 2nd ed. Oxford: Blackwell; 1992. p.3
2. Bakonyi SMC, Danni-Oliveira IM, Martins LC, Braga ALF. Air pollution and respiratory diseases among children in the city of Curitiba, Brazil. Rev Saúde Pública. 2004;38:675-700.

3. Gouveia N, Mendonça GAS, Leon AP, Correia JEM, Junger WL, Freaitas CU, et al. Poluição do ar e efeitos na saúde nas populações de grandes metrópoles brasileiras. Epidemiol Serv Saúde. 2003;12:29- 40.
4. American Academy of Pediatrics. Committee on Environmental Health. Ambient air pollution: health hazards to children. Pediatrics. 2004;114; 1699-707.
5. Brauer M, Hoek G, Smit HA, Jongste JC, Gerritsen J , Postma DS, et al. Air pollution and development of asthma, allergy and infections in a birth cohort. Eur Respir J. 2007;29:879-88.
6. Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, et al. The effect of air pollution on lung development from 10 to 18 years of age. 2004. N Engl J Med. 2004;351:1057-67.
7. Nascimento LFC, Pereira LAA, Braga ALF, Módolo MCC, Carvalho Jr JA. Efeitos da poluição atmosférica na saúde infantil em São José dos Campos, SP. Rev Saúde Pública. 2006;40:77-82
8. Hiltermann TJ, Stolk J, Van Der Zee SC, Brunekreef B, De Bruijne CR, Fisher PH, et al. Asthma severity and susceptibility to air pollution. Eur Respir J. 1998;11:686-93.
9. Pope CA, Dockery DW. Health effects of fine particulate air pollution: lines that connect. J Air Waste Manage Assoc. 2006;56:709-42.
10. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution. Am J Respir Crit Care Med. 1996;153:3-50
11. Mascarenhas MDM, Vieira LC, Lanzieri TM, Leal APPR, Duarte AF, Hatch DL. Anthropogenic air pollution and respiratory disease-related emergency room visits in Rio Branco, Brazil - September, 2005. J Bras Pneumol. 2008;34:42-6.
12. Prietsch SOM, Fischer GB, César JA, Cervo PV, Sangaletti LL, et al. Fatores de risco para sibilância recorrente em menores de 13 anos no Sul do Brasil. Rev Panam Salud Publica. 2006:20:331-7.
13. Brasil. Portal da Saúde. SUS. Asma grave. [cited 29 Jan 2012]. Available from: http://portal.saude.gov.br/saude/visualizar_texto.cfm?idtxt=23509.
14. Casagrande RRD, Pastorino AC, Souza RGL, Leone C, Solé C, Jacob CMA. Presença de asma e fatores de risco em escolares da cidade de São Paulo. Rev Saúde Pública. 2008;42:517-23.
15. Solé D, Wandalsen GF, Camelo-Nunes IC, Naspitz CK; ISAAC - Grupo Brasileiro. Prevalence of symptoms of asthma, rhinitis, and atopic eczema among Brazilian children and adolescents identified by the international study of asthma and allergies in childhood (ISAAC) - phase 3. J Pediatr (Rio J). 2006;82:341-6.
16. González Gómez JG, Barrera Gómez LE, ArévaloOrozco MA. Prevalencia del asma bronquial en la ciudad de Guadalajara, Jalisco, México. Alergia. 1992;39:3-7
17. Corrêa MFP, Melo GO, Costa SS. Substâncias de origem vegetal potencialmente úteis na terapia da asma. Rev Bras Farmacogn. 2008;18(Supl):785-97.
18. Brasil. Datasus. [cited 14 Oct 2009]. Available from: http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sih/cnv/mrsp.def.
19. Prefeitura Municipal de São José dos Campos. [cited 4 Feb 2010]. Available from: http://www.sjc.sp.gov.br/acidade/populacao.asp.
20. Brasil. Departamento de Informações e Informática do Sistema Único de Saúde, DATASUS. [cited 16 Sept 2009]. Available from: http://w3.datasus.gov.br/datasus/index.php.
21. Companhia de Tecnologia de Saneamento Ambiental, CETESB. [cited 16 Sept 2009]. Available from: http://www.cetesb.sp.gov.br.
22. Fundação de Ciência, Aplicações e Tecnologia Espaciais, FUNCATE. [cited 16 Sept 2009]. Available from: http://www.funcate.org.br/.
23. Gouveia N, Freitas CU, Martins LC, Marcilio IO. Hospitalizações por causas respiratórias e cardiovasculares associadas à contaminação atmosférica no município de São Paulo, Brasil. Cad Saúde Pública. 2006;22:2669-77.
24. Organização Mundial da Saúde. Air quality guideline. [cited 24 Sept 2009]. Available from: http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf.
25. Braga AL, Saldiva PH, Pereira LA, Menezes JJ, Conceição GM, Lin CA, Zanobetti A, Schwartz J, Dockery DW. Health effects of air pollution exposure on children and adolescents in São Paulo, Brazil. Pediatr Pulmonol. 2001;31:106-13.
26. Castro HA, Cunha MF, Mendonça GAS, Junger WL, Cunha-Cruz J, Leon AP. Efeitos da poluição do ar na função respiratória de escolares, Rio de Janeiro, RJ. Rev Saúde Pública. 2009;43:26-34.
27. Gouveia N, Fletcher T. Respiratory diseases in children and outdoor air pollution in São Paulo, Brazil: a time series analysis. Occup Environ Med. 2000; 57:477-83.
28. Veras C, Martins M. A confiabilidade dos dados nos formulários de Autorização de Internação Hospitalar (AIH), Rio de Janeiro, Brasil. Cad Saúde Pública. 1994;10:339-55.
29. Brasil. Ministério do Meio Ambiente. Resolução Conama 03/1990. [cited 20 Jan 2012]. Available from: http://www.mma.gov.br/port/conama/legipesq.cfm?tipo=3&numero=03&ano=1990&texto=.